# Systematics of the Hawaiian *Littorina* Ferussac

(Mollusca : Gastropoda)

BY

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(Plates 25 and 26; 4 Text figures)

## INTRODUCTION

The gastropod genus *Littorina* Ferussac is represented in the Hawaiian Islands by five species. Two of these species, *Littorina pintado* (Wood) and *Littorina picta* Philippi are the predominant animals in the supratidal region of the rocky coast of Oahu. A third species, *Littorina scabra* (Linnaeus), occurs on protected shores such as are found along breakwaters and harbors and in some areas, on the roots of mangrove trees. The fourth species, *Littorina undulata* Gray, is relatively rare. An additional unidentified species is represented by only one specimen.

On Oahu, *Littorina pintado* and *L. picta* are usually sympatric in the same supratidal areas. These two species have very similar ecological relationships.

Preliminary observations of the shells of *Littorina pintado* and *L. picta* suggested that they were specifically distinct. However, since many species of *Littorina* show a great range of variability in the shell and furthermore, since these species are so similar ecologically, the possibility existed that *L. pintado* and *L. picta* might not be valid species. Therefore, an attempt was made to determine the morphological characteristics which might provide a broader basis for an understanding of their taxonomic relationship.

It also appeared that what have previously been termed varieties of *Littorina picta* (*L. picta* Philippi *and L. picta* var. *marmorata* Philippi) might possibly be distinct species, since each variety predominates in a different area. The relationship of these varieties was also studied.

Finally, an attempt was made to study the morphological characteristics of *Littorina scabra* which might clarify its relationship to *L. pintado* and *L. picta*. Although the habitats of the three species rarely overlap, occasionally *L. scabra* is found in proximity to *L. pintado* and *L. picta*, and smaller individuals of the three species resemble each other to some degree.

Only five specimens of *Littorina undulata* and one specimen of an undetermined species (*Littorina* sp.) were collected. The shells of these specimens are described below. The radulae and internal morphology, however, were not studied.

Because of the controversy over the generic and subgeneric names proposed for the species of *Littorina* (Wingkworth, 1922), the generic name *Littorina* is retained for all the Hawaiian species. The subgeneric names are omitted in the discussion.

The entire anatomy of *Littorina pintado, L. picta* and *L. scabra* was studied, but only those morphological characteristics which were found to be diagnostic are discussed; shell, radula, male reproductive system, egg capsule and developmental type.

## MATERIALS and METHODS

Collections of specimens were made at various times over a three year period from 1961 to 1963. For determinations of height and width of shell, collections of snails were made at random from several different areas, since the mean sizes were observed to vary between different substrata. The height to width ratio, however, is based only on measurements of snails collected near the Waikiki Aquarium, Oahu. Measurements of the shells were made with vernier calipers to the nearest 0.1 mm. The dimensions utilized are shown in Figure 1.

For anatomical studies, the specimens dissected and described were collected primarily from Coconut Island and near Waikiki Aquarium, Oahu. These specimens were selected because of their larger size and infrequent shell erosion. All dissections were made of living material under a binocular microscope. The results, except where otherwise indicated, are based on the dissection and exam-

[1] This paper is part of a thesis submitted to the Graduate School of the University of Hawaii in partial fulfillment of the requirements for the Ph.D. degree.

ination of at least 50 individuals of each species. Measurements of various anatomical parts, egg capsules or eggs were made either with a millimeter ruler (nearest 1.0 mm), vernier calipers (nearest 0.1 mm) or a micrometer (nearest 0.001 mm). The radulae were fixed and stained by KAY's (1957) modification of the techniques employed by ALLEN (1952) and BOWELL (1924).

*Littorina pintado* (WOOD)
(Plate 25, Figure 1)

*Turbo pintado* WOOD, 1828, Index Test. Suppl., p. 224, Suppl. pl. 6, fig. 34 (Sandwich Islands).

*Littorina pintado* PHILIPPI, 1847, Abbild. und Beschr. Conch., pl. 4, fig. 20 (Sandwich Islands); REEVE, 1857, Conch. Icon., X, *Littorina,* pl. 11, figs. 54 a - b. (Sandwich Islands).

## DISTRIBUTION

This species is distributed from Japan through the Pacific Ocean to the Hawaiian Islands.

## DESCRIPTION

**Shell:** There is little variation in the pattern of the shell of this species. However, eroded shells, on which the pattern is obscured, are common. The color of the shell is also fairly constant, but is lighter in some specimens because of slight surface erosion. The shells of larger and older specimens, for example, are frequently lighter in appearance than those of younger specimens. Some individuals, particularly those found in tidepools, appear darker because of algae growing on the whorls and in the sutures of the shell. The following description is based mainly on uneroded shells of younger specimens where the pattern could be seen clearly.

The shells are conoidal, of medium thickness and usually consist of seven fairly well-rounded whorls. The last two whorls in the spire are small and frequently eroded in older specimens. The surface is generally smooth, with shallow spiral lines. The shell is never ribbed strongly or beaded granularly. The axial sculpture is confined to growth striae. The pattern on the shells of larger individuals is sometimes faded. The ground color is usually pale bluish-gray on all whorls except the last one to two whorls in the spire, which are entirely reddish-brown. The five largest whorls are freckled with dark brown or black in the form of small spots which are darker toward the base of the whorls and fade toward the summit of the whorls. The aperture is oval and its outer lip thin and smooth. The external pattern can be seen within the aperture as solid, parallel, brown lines. The columella is glazed, slightly curved, dark red-brown laterally and white at its junction with the operculum.

The size range and mean size of shells vary between different areas and substrata. The ranges in size and mean sizes of shells from several different areas are summarized in Table 1. The maximum height observed in *Littorina pintado* was 22.0 mm. The apical angle in uneroded specimens is usually approximately 50 to 55°. There is sexual dimorphism in shell size, the mean size of females being significantly larger than that of males. This is shown in Table 2. The shell height to width ratio of 1.62 is the same in both sexes and fairly constant between individuals (Table 2).

### Table 1

Summary of Size Distribution (mm height) on Palagonite Tuff Substratum (Koko Head and Hanauma Bay); Reef Limestone Substratum (Kahuku Point and Kaena Point); Artificial Substratum (Waikiki).

| Area and Species | Sample Number | Mean Size Whole Area | Range Size Whole Area |
|---|---|---|---|
| Hanauma Bay | | | |
| *Littorina pintado* | 624 | 4.92 | 1.9 - 8.2 |
| *Littorina picta* | 540 | 3.66 | 1.6 - 7.0 |
| Koko Head | | | |
| *Littorina pintado* | 218 | 4.77 | 1.3 - 8.5 |
| *Littorina picta* | 131 | 3.37 | 1.7 - 6.8 |
| Kaena Point | | | |
| *Littorina pintado* | 448 | 8.20 | 2.6 - 14.0 |
| *Littorina picta* | 29 | 5.14 | 2.6 - 8.3 |
| Waikiki | | | |
| *Littorina pintado* | 322 | 8.80 | 4.6 - 13.3 |
| *Littorina picta* | 296 | 7.00 | 3.6 - 10.3 |
| Kahuku Point | | | |
| *Littorina pintado* | 156 | 10.70 | 5.4 - 16.2 |
| *Littorina picta* | 16 | 6.07 | 3.4 - 8.3 |

**Radula:** The total length and width of the radula are given in Table 3. The radula varies considerably in length, but is less variable in width. The mean length of the radula in the specimens examined is approximately 36.0 mm and the mean width is approximately 0.190 mm. As in other species of *Littorina,* there are seven teeth in a transverse row. The radular teeth from one side of a transverse row are depicted in Figure 2 a - d. Only the bases of the rachidian and outer marginal teeth are shown, since the other teeth bases could not be seen clearly. The rachidian tooth in *L. pintado* is high-crowned, with three anterior, elongated and rounded cusps. At the base are three denticles. The central denticle is rounded, the lateral denticles are pointed. These denticles are slightly more

## Table 2

Summary of Shell Measurements (in millimeters) and Analysis of Variance between Mean Height of Males and Mean Height of Females for *Littorina picta, Littorina pintado* and *Littorina scabra.* (All specimens collected at random; all are adults).

| | Mean Height | Range Height | Height Interval | Mean Width | Range Width | Width Interval | Mean H/W | $S^2$ | $S_{\bar{x}}$ | t(Height only) | n |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Littorina picta* | | | | | | | | | | | |
| female | 7.52 | 5.0 - 10.3 | 5.3 | 4.84 | 3.1 - 6.5 | 3.4 | 1.56 | 1.46 | 0.24 | 4.29**, d.f. 98 | 50 |
| male | 6.49 | 3.6 - 8.5 | 4.9 | 4.15 | 2.2 - 5.6 | 3.4 | 1.56 | | | | 50 |
| *Littorina pintado* | | | | | | | | | | | |
| female | 9.26 | 5.8 - 13.3 | 7.5 | 5.73 | 3.7 - 8.6 | 4.9 | 1.62 | 2.39 | 0.31 | 3.02**, d.f. 98 | 50 |
| male | 8.33 | 4.6 - 10.7 | 6.1 | 5.15 | 3.0 - 6.5 | 3.5 | 1.62 | | | | 50 |
| *Littorina scabra* | | | | | | | | | | | |
| female | 21.6 | 18.2 - 26.6 | 8.4 | 11.70 | 10.5 - 13.7 | 3.2 | 1.84 | 4.52 | 0.61 | 5.74**, d.f. 48 | 22 |
| male | 18.1 | 12.5 - 22.7 | 10.2 | 10.23 | 7.0 - 11.7 | 4.7 | 1.84 | | | | 26 |

H/W - Height/Width Ratio
$S^2$ - Pooled Variance
$S_{\bar{x}}$ - Standard Error
t - Test
n - Sample number
d.f. - Degrees of freedom

## Table 3

Dimensions of Radula, Radular Teeth and Number of Cusps of *Littorina pintado, Littorina picta,* and *Littorina scabra*

| Species | N | RTL (mm) | ML (mm) | RTW (mm) | MW (mm) | Tooth | Microns L | Microns W | No. Cusps | Cusp Shape |
|---|---|---|---|---|---|---|---|---|---|---|
| *Littorina pintado* | 20 | 22 - 55 | 36 | 0.18 - 0.20 | 0.19 | Rachidian | 70 | 60 | 3 | Rounded |
| | | | | | | Lateral | 40 | 70 | 3 | Rounded |
| | | | | | | Inner Marginal | 30 | 70 | 4 | Rounded |
| | | | | | | Outer Marginal | 70 | 40 | 4 | Rounded |
| *Littorina picta* | 20 | 16 - 35 | 23 | 0.10 - 0.16 | 0.12 | Rachidian | 40 | 30 | 3 | Rounded |
| | | | | | | Lateral | 40 | 30 | 3 | Rounded |
| | | | | | | Inner Marginal | 30 | 30 | 4 | Rounded |
| | | | | | | Outer Marginal | 40 | 20 | 4 | Pointed[1] |
| *Littorina scabra* | 20 | 25 - 39 | 32 | 0.50 - 0.55 | 0.54 | Rachidian | 100 | 140 | 3 | Rounded |

[1] In *Littorina picta* (ribbed variety) the cusps may be either missing or rounded, while in *L. picta* var. *marmorata* (smooth variety) the cusps are nearly always pointed and 4 in number.

N - number of specimens examined; RTL - range in total length; ML - mean length; RTW - range in total width; MW - mean width; L - length; W - width. The above measurements of radular teeth are averages only.

accentuated than those of the rachidian tooth of *L. picta* (Figure 2 e). The rachidian tooth is fairly constant in appearance between individuals and does not show as much wear as the other teeth. The lateral and marginal teeth show some variation in cusping in the anterior rows of the radula because of differential wear. The lateral tooth usually has three rounded anterior cusps and the inner marginal tooth has three to four rounded anterior cusps. The outer marginal tooth usually has four marginal cusps, also rounded.

The maximum dimension of the rachidian tooth in *Littorina pintado* is approximately 70 microns from the crown to the base. The approximate sizes of other teeth are summarized in Table 3.

**Male Reproductive System:** The penis of *Littorina pintado* is depicted in Figure 3 a. In mature males, the average length of the penis ranges from 4.0 to 4.5 mm and the width averages approximately 1.0 mm. There are no apparent penial glands at the base of the penis of this species, although some type of gland may be present, inconspicuously imbedded. There is no separate base, the penis joining directly to the body. The color of the penis is white, never red as in *L. picta*. The testicular duct in mature males is usually yellow-white in color.

**Egg Capsules and Developmental Type:** The egg capsule of *Littorina pintado* is depicted in Plate 26, Figure 1 as it appears in polar and lateral views. The outer egg capsule averages 160 microns in diameter from a dorsal or ventral aspect. Laterally, the average maximum dimension is 100 microns. The inner egg covering averages 65 microns and the egg 60 microns in diameter. There is never more than one egg per capsule in normal capsules. Among the many thousands of egg capsules and different spawns examined, only one group of aberrant capsules containing more than one egg per capsule was observed. The reason for this aberrant spawn was not ascertained. Generally, the appearance and size of the capsules is highly uniform between different individuals. Development is oviparous with the release of egg capsules into the plankton. Breeding and spawning are continuous throughout the year.

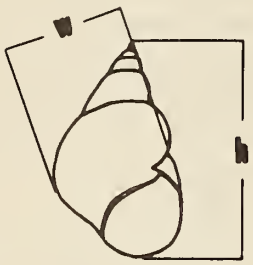


Figure 1: Dimensions of Shell measured.
h = height w = width

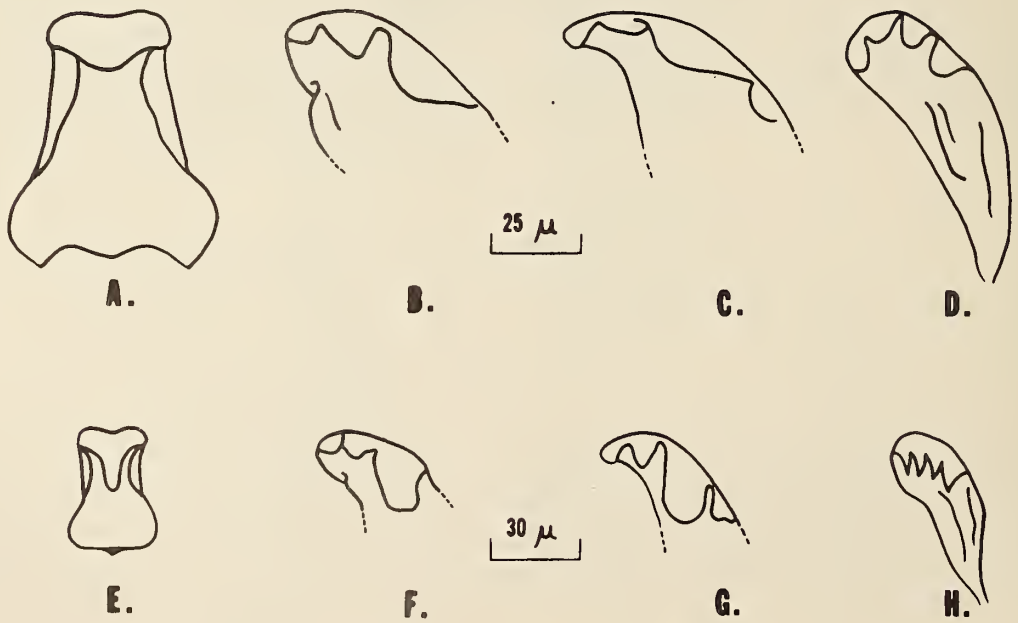


Figure 2: Radular Teeth from one Side of Transverse Row.
Anterior Edge toward Top of Page.

a to d: *Littorina pintado*. x 600.
a - rachidian tooth; b - lateral tooth; c - inner marginal tooth; d - outer marginal tooth

e to h: *Littorina picta* (same in *L. picta* var. *marmorata*). x 525
e - rachidian tooth; f - lateral tooth; g - inner marginal tooth; h - outer marginal tooth.

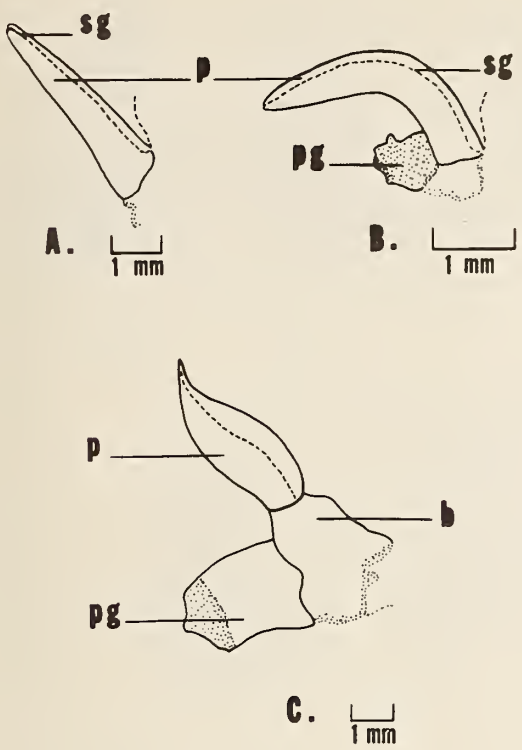


Figure 3: Penes of adult Males. Anterior View. All Penes Slightly Contracted.
A. *Littorina pintado.* x 8.
B. *Littorina picta* (Same in *L. picta* var. *marmorata*). x 10.
C. *Littorina scabra.* x 6.
b - base; p - penis; pg - penial gland; sg - sperm groove

*Littorina picta* PHILIPPI
(Plate 25, Figure 2)

*Littorina picta* PHILIPPI, 1845, Proc. Zool. Soc., p. 139 (Sandwich Islands).

*Littorina picta* var. *marmorata* PHILIPPI, 1847, Abbild. und Beschr. Conch., pl. 3, fig. 26 (Sandwich Islands); REEVE, 1857, Conch. Icon. X, *Littorina,* pl. 15. figs. 80 a - b and fig. 81.

## DISTRIBUTION

This species is distributed throughout the Hawaiian Islands. There are no definite records from any other area. *Nodolittorina picta,* from Japan, is probably not the same species (see discussion).

## DESCRIPTION

**Shell:** The two varieties are variable in the degree of ribbing on the shell. The variety with well-marked spiral ribs is *Littorina picta* (Plate 25, Figures 2 a and b) and the smooth variety is *L. picta* var. *marmorata* (Plate 25, Figures 2 e to h). Many individuals, however, show various gradations in shell-ribbing between these two extremes (Plate 25, Figures 2 c and d). One variety usually predominates over the other depending upon the area. At Pokai Bay and Haleiwa, Oahu, for example, the ribbed variety is common and smooth forms are rare. In other areas, such as Koko Head and Hanauma Bay, the smooth forms are common and the ribbed forms rare. There are also areas, such as Waikiki and Coconut Island, Oahu, which have populations of *L. picta* including both ribbed and smooth varieties and various intergrades between the two extremes.

In the following shell description the two varieties are discussed separately and a few comments are made upon the appearance of the intergrading forms.

*Littorina picta* var. *marmorata:* The shells are conoidal, slightly thicker than those of *Littorina pintado* and usually consist of six fairly well-rounded whorls. The last three whorls in the spire are small and often eroded in older specimens. The surface of this variety is smooth with shallow, spiral lines and is not strongly ribbed and/or granularly beaded. The axial sculpture is confined to growth striae. The color and pattern of the shell are extremely variable except for the last one to two whorls in the spire, which are usually reddish-brown. The pattern on the other whorls varies between the following three basic types: 1) Ground color dark grey, brown or black on three largest whorls, sometimes a few small, white spots on summit of body whorl and/or summit of other whorls; 2) Ground color black, but white spots always present, usually in one to two rows around base of body whorl, one row of large white spots at summit of body whorl, sometimes a row of white spots at the summit of next two whorls; 3) Ground color white with a few irregular black patches or shell entirely white. The aperture is oval and its outer lip thin and smooth. The external pattern can be seen within the aperture. The columella is glazed, slightly curved, usually purple, but sometimes white.

**Intermediate forms:** These forms are similar to *Littorina picta* var. *marmorata,* except that the whorls of the spire and sometimes other whorls possess thickened ridges or ribs which follow the spiral lines. The body whorl is usually smooth or slightly ribbed with no granular beading on ribs or slight beading only.

*Littorina picta:* This variety is similar to *Littorina picta* var. *marmorata,* except that the spiral lines are thickened into strong ribs on all whorls. There are usually regularly spaced, granular beads present on the ribs. The variable color patterns are the same as in *L. picta* var. *marmorata,* except that the overall appearance may be darker because

the pattern is obscured by the ribs. The aperture is oval and the outer lip thin. In this variety the outer lip is serrated in line with the external spiral ridges.

The shells of both varieties are sometimes discolored from erosion and appear solid black or dark brown. Extreme erosion in the form of pitting is not common in this species as it is in *Littorina pintado,* and in general the shell seems harder and thicker.

The size range varies between areas and substrata. The ranges in size and mean sizes of populations from several different areas on Oahu are given in Table 1. As in *Littorina pintado,* the mean size of shell of *L. picta* is less on palagonite tuff substrata than on other substrata. The maximum height observed in *L. picta* was approximately 13.0 mm(ribbed variety). The apical angle in uneroded specimens is usually 50 to 55°. As in *L. pintado,* there is sexual dimorphism in shell size, the mean size of females being significantly greater than that of males (Table 2). The shell height to width ratio is 1.56, the same in both sexes and varies little between individuals (Table 2).

**Radula:** The radulae of the varieties of *Littorina picta* were found to be similar. Therefore, they are jointly discussed in this section. The few differences which do exist will also be discussed. The mean total length and width of the radula are given in Table 3. In *L. picta* there is also considerable variation in the length of the radula. The mean length is approximately 23.0 mm for the specimens examined. The width is less variable and is approximately 0.120 mm. The radular teeth from the right side of a transverse row are depicted in Figure 2 e - h. The rachidian in this species is high-crowned, with three anterior, elongated and rounded cusps, the largest in the center of the crown. At the base of the rachidian tooth are three small denticles. In *L. picta* the lateral denticles are rounded while the central denticle is pointed, the reverse being the case in *L. pintado.* As in *L. pintado,* the rachidian tooth is relatively constant in appearance between individuals, while the lateral and marginal teeth show some variation associated with wear of the cusps. The lateral tooth in most individuals of both varieties possesses three to four rounded anterior cusps. The inner marginal tooth in both varieties possesses three to four rounded cusps also. On the anterior edge of the outer marginal tooth of *L. picta* var. *marmorata* there are usually four pointed anterior cusps. In the ribbed variety, *L. picta,* these four cusps on the outer marginal tooth are also pointed in the posterior rows, but often absent or eroded in the anterior rows of the radula.

The radular teeth of *Littorina picta* are small, the maximum dimension of the rachidian being only 40 microns from crown to base. The sizes of other teeth are summarized in Table 3.

**Male Reproductive System:** The males of both varieties were dissected and their genitalia compared. No significant difference between the varieties was observed, thus the following description applies to both. The penis and accompanying glands are depicted in Figure 3 b. The average length of the penis in mature males ranges from approximately 3.0 to 3.5 mm. The width averages from 0.50 to 0.75 mm. The base of the penis joins the body directly and is not borne on a separate base. It is red in color. There are white penial glands in this species which extend to the right of the base of the penis. The testicular duct of the mature males appears to be characteristically red.

**Egg Capsules and Developmental Type:** The egg capsule of *Littorina picta* is shown in Plate 26, Figure 2 in lateral, dorsal and ventral views. The capsule is distinct from that of *L. pintado,* possessing several concentric ridges. The capsule and egg of *L. picta* are also larger than those of *L. pintado.* The outer egg capsule averages 180 microns in diameter from dorsal or ventral view. Laterally, the maximum dimension averages approximately 120 microns. The inner egg covering averages approximately 80 microns and the egg 75 microns in diameter. There was only one egg

## Explanation of Plate 25

Figure 1: *Littorina pintado.* Adult Shells. x 2⅔
a. Dorsal View of Uneroded Shell. Waikiki, Cement and Basalt Boulder Breakwater.
b. Ventral View of Uneroded Shell. Waikiki, Cement and Basalt Boulder Breakwater.
c. Dorsal View of Eroded Shell. Koko Head, Palagonite Tuff Bench.
Figure 2: *Littorina picta* and *Littorina picta* var. *marmorata,* and intermediate forms. Adult Shells. x 3½.
a and b: *Littorina picta* (ribbed variety). Pokai Bay, Reef Limestone Bench.
c and d: Intermediate forms. Waikiki, Cement and Basalt Boulder Breakwater.
e to h: *Littorina picta* var.*marmorata* (smooth variety). Koko Head, Palagonite Tuff Bench.
Figure 3: *Littorina scabra.* Adult Shells. x 2. Coconut Island, Concrete Wall.
Figure 4: *Littorina undulata.* Adult Shells. x 2¾.
a and b: Waikiki, Concrete and Basalt Boulder Breakwater.
c and d: Bellows Field, Reef Limestone Artificial Breakwater.
Figure 5: *Littorina* sp. Adult Shell. x 2¾. Coconut Island. Concrete Wall.

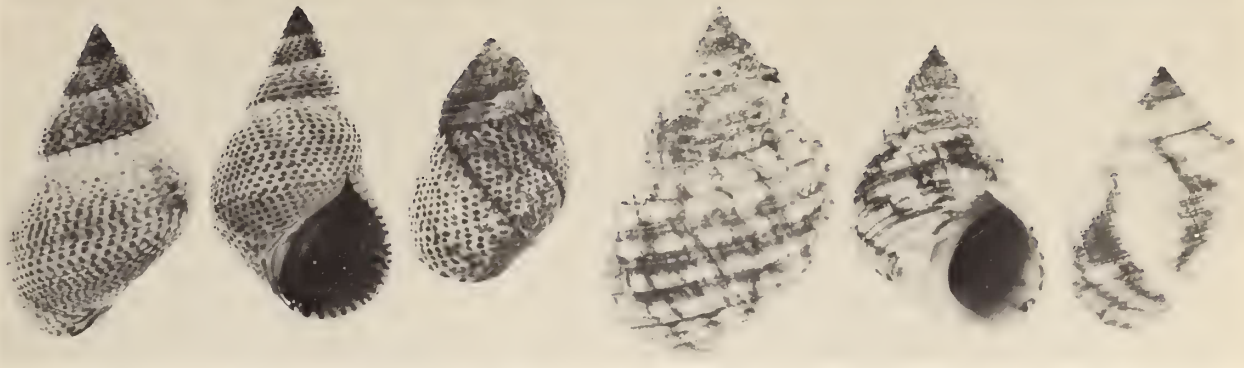

Figure 1a Figure 1b Figure 1c Figure 2a Figure 2b Figure 2c

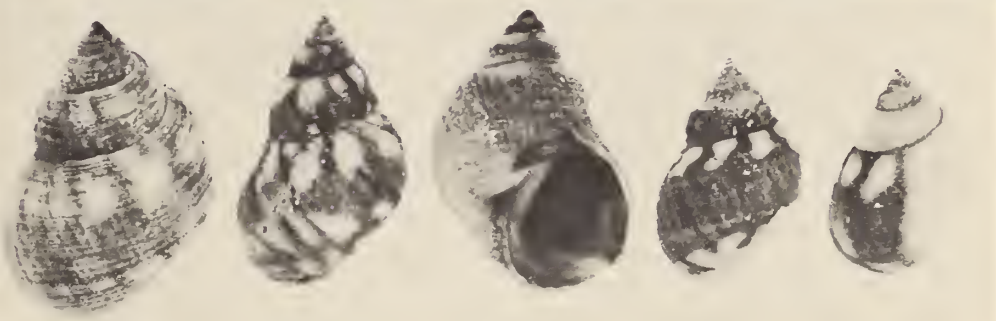

Figure 2d Figure 2e Figure 2f Figure 2g Figure 2h

Figure 3a Figure 3b Figure 3c

Figure 5a Figure 5b

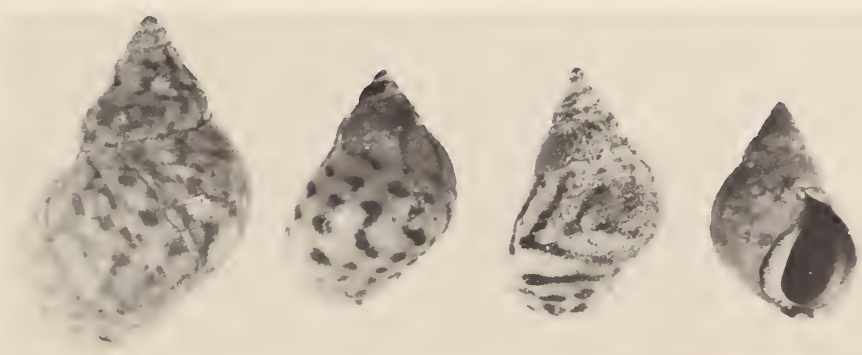

Figure 4a Figure 4b Figure 4c Figure 4d

per capsule in all the spawns examined. The appearance of the capsules is uniform between different individuals and between the two varieties. Development is oviparous as in *L. pintado*, the eggs developing in the plankton. This species, as well as *L. pintado*, breeds continuously throughout the year.

*Littorina scabra* (Linnaeus)
(Plate 25, Figure 3)

*Helix scabra* Linnaeus, 1758, Syst. Nat. ed. 10, p. 770.
*Littorina scabra* Reeve, 1857, Conch. Icon. X, *Littorina*, pl. 5, figs. 21 a - b and pl. 3, fig. 15 a, (Philippine Islands).
*Littorina newcombi* Reeve, 1857, Conch. Icon., X, *Littorina*, pl. 6, figs. 28 a - b, (Sandwich Islands).
*Littorina ambigua* (Nuttall, MS.), Reeve, 1857, Conch. Icon. X, *Littorina*, pl. 12 fig. 64, (Sandwich Islands).

## DISTRIBUTION

The distributional range of *Littorina scabra* extends from the West Coast of Africa through the Indopacific to the Hawaiian Islands and the West Coast of California; Australia and Japan.

## DESCRIPTION

**Shell:** There is considerable color variation in this species on Oahu and some variation in pattern. However, there is little variation in shell sculpture among Oahu specimens, all examined being generally smooth. The shells are not greatly eroded.

The shells are conoidal and relatively thick. There are eight well-rounded whorls; the last two whorls in the spire are small but not usually eroded. The surface is generally smooth, but possesses well-marked spiral lines. The last spiral line at the summit of each whorl is particularly well-marked. The shells are never ribbed or granularly beaded in the Oahu specimens. The axial sculpture is confined to growth striae. The three common color varieties are: 1) Ground color light-gray or brown, sometimes with bluish tinge; marked with light or dark brown dashes which parallel the spiral lines. The variability in the pattern is due to differences in spacing of these dashes. The dashes are usually not adjacent to each other in the axial direction and the shell appears to have irregular brown zigzag lines down the whorls. The dashes are usually darker at the base of the whorls and lighter or absent at the summit of the whorls. The above description is of the most commonly observed color pattern. Less common are: 2) ground color yellow or yellow-orange, other features as in (1); and 3) ground color rose, other features as in (1), except that several bands at the summit of the whorls (delimited by spiral grooves) are solid rose with no brown dashes.

The pattern of the shell and the color are sometimes faded by surface erosion, giving the shell an overall bluish-gray color.

The aperture is oval and the outer lip thin and smooth. The external pattern can be seen within the aperture. The general color within the aperture is usually yellow and sometimes rose. The columella is glazed, slightly curved, dark-brown and/or white.

The size range in this species was determined from specimens collected from the Coconut Island population only. The size range and mean size of *Littorina scabra* at this locality are given in Table 2. The maximum height observed in Oahu specimens of *L. scabra* was 36.0 mm. The shell height to width ratio is 1.84 (Table 2). The same type of sexual dimorphism as occurred in the previous two species is also present in *L. scabra* (Table 2).

**Radula:** The radula of *Littorina scabra* is much wider than that of either *L. picta* or *L. pintado*, but is not as long as that of *L. pintado*, even though *L. scabra* is a much larger species. The mean length of the radula is approximately 32.0 mm and the width approximately 0.540 mm (Table 3). The dimensions of the rachidian tooth are also given in Table 3. The rachidian of *L. scabra* is quite distinct from those of *L. pintado* and *L. picta* (Figure 4).

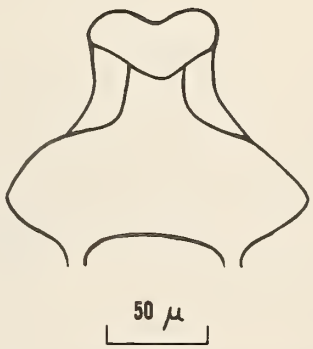


Figure 4: *Littorina scabra*. Rachidian Tooth. x 360. Anterior Edge toward Top of Page.

It is low-crowned, the base is quite flaring and the tooth is much larger. As in *L. pintado* and *L. picta* there are three anterior rounded cusps, the largest occurring in the center of the crown, but the location of the three denticles at the base is quite different. The maximum dimension of the rachidian is across the base and measures 140 microns (Table 3).

**Male Reproductive System:** The penis of *Littorina scabra* is depicted in Figure 3 c and is significantly different from that of *L. pintado* and *L. picta* in that it is borne on a separate base instead of joining into the body directly. The

length of the penis in mature males ranges from 4.5 to 5.0 mm and the width is approximately 2.0 mm. The color of the penis is yellow-white. The penial gland is white and well-developed in this species.

**Eggs and Mode of Development:** *Littorina scabra* is ovoviviparous and does not release planktonic egg capsules as do *L. pintado* and *L. picta,* but develops eggs within the mantle cavity to a late veliger stage, at which time they are shed into the water. There is no external capsule as in *L. pintado* and *L. picta.* A simple egg covering, however, is present and measures approximately 80 microns in diameter. The egg is approximately 75 microns in diameter. This species also breeds continuously throughout the year.

### *Littorina undulata* Gray
(Plate 25, Figure 4)

*Littorina undulata* Gray, 1839, Zool. Beechey's Voy., p. 140, no figures; Reeve, Conch. Icon. X, *Littorina,* pl. 13, figs. a, b, c, d, (Society and Philippine Islands).

### DISTRIBUTION

The distribution of this species is from Japan and Australia through the Pacific to the Society and Philippine Islands and also Johnston Islands. It has not been previously noted from the Hawaiian Islands, except by Tinker (1958).

### DESCRIPTION

**Shell:** Only four specimens of *Littorina undulata* were found on Oahu during this study. Two of the specimens were collected from an artificial sea wall near Waikiki Aquarium, and two from an artificial sea wall at Bellows Field Air Force Base. None of the specimens are very large (compared to those in the Bishop Museum collections), the largest being approximately 16.5 mm in height and 9.6 mm in width. All four have green algae on the surface of the shell and all four are slightly eroded, obscuring the pattern to some degree. The basic pattern, however, can be seen partially.

The shell is conoidal and of medium thickness. There are from 6 to 7 fairly well-rounded whorls. This could not be determined exactly because the spires of all four specimens were eroded. The surface is smooth with a few shallow, spiral lines. None of the specimens are ribbed or granularly beaded. The axial sculpture is confined to growth striae and the sutures are well-constricted. The ground color is light gray or tan on the three largest whorls. The whorls are marked with irregular, light red-brown zigzag lines. The aperture is oval and the outer lip thin and smooth. The external pattern can be seen within the aperture in the form of brown spots on a yellow background. The columella is glazed, slightly curved, purple laterally and white at its junction with the operculum.

The sizes of the specimens are 16.5 x 9.6 mm, 12.4 x 7.5 mm, 11.8 x 7.2 mm, and 11.2 x 6.8 mm. The mean shell height to width ratio based on the four specimens is 1.69.

### *Littorina* sp.
(Plate 25, Figure 5)

One female specimen of an undetermined species was found at Coconut Island in February 1963. It was located on the southeastern concrete sea wall near the entrance of the lagoon and found next to several specimens of *Littorina pintado* and *L. picta.* Its appearance was sufficiently different from that of the other species so that it was immediately noticed. Attempts to identify this species were unsuccessful since no description from the literature seemed to fit this particular specimen. The closest resemblance is to the shell of *Littorina zebra* (Wood) (Reeve, 1857). An examination of the collections of the Bishop Museum did not reveal any shells collected from the Hawaiian Islands which resembled this specimen.

### DESCRIPTION

**Shell:** The specimen is not eroded and thus the pattern and number of whorls can be seen clearly.

The shell is conoidal and relatively thick. There are seven well-rounded whorls. There is no deciduous periostracum and the surface is smooth. The spiral lines are not well indented. The axial sculpture is confined to growth striae. The ground color is white. The body whorl of the shell is marked with irregular zigzag lines in the axial direction. These lines are relatively broad and dark chocolate brown in color. The next four whorls of the spire are solid chocolate brown in color and the last two whorls of the spire are light reddish-brown. The aperture is oval and the outer lip thin and smooth. The color and pattern within the aperture are similar to the external pattern of the body whorl. The columella is glazed, slightly curved, and purple in color.

## Explanation of Plate 26

Figure 1: *Littorina pintado.* Egg Capsules Immediately after Spawning. Eggs in One-Cell Stage. At Far Left is a Capsule in Lateral View, the Others are in Polar View. x 175.

Figure 2: *Littorina picta* (Same in *Littorina picta* var. *marmorata*). Egg Capsules Immediately after Spawning. Eggs in One-Cell Stage. At Left Center is a Capsule in Lateral View, the Others are in Polar View. x 175.

Figure 1

Figure 2